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# Synthesis of Optically Pure 1,2-Diaryl- and 1,2-Alkylaryl-1,2-amino Sulfides

Yolanda Arroyo,*,† Ángela Meana,† J. Félix Rodríguez,† Mercedes Santos,† M. Ascensión Sanz-Tejedor,*,† and José. L. García Ruano*,‡

*Departamento de Química Orgánica (ETSII), Universidad de Valladolid, Po. del Cauce s/n, 47011 Valladolid, Spain, and Departamento de Química Orgánica (C-I), Universidad Autónoma, Cantoblanco, 28049 Madrid, Spain*

*atejedor@dali.eis.uva.es; joseluis.garcia.ruano@uam.es*

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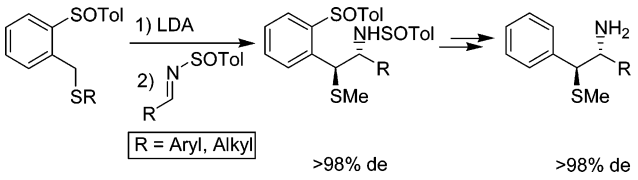


The reactions of the lithium (*S*)-α-(methylthio)-2-(*p*-toluenesulfinyl)benzyl carbanion with (*S*)-*N*-*p*-tolylsulfinyl aldimines evolve in a completely stereoselective manner providing a one-step synthesis of enantiomerically pure *anti*-1,2-disubstituted 1,2-amino sulfide derivatives.

## Introduction

Enantiomerically pure 1,2-amino sulfides and 1,2-amino thiols are structural subunits of undoubted synthetic interest in organic chemistry. They have been proven very successful as N,S-ligands in enantioselective reactions such as palladium-catalyzed allylic substitution,[1] addition of alkyllithium to aldehydes,[2] iridium(I)-catalyzed reduction of unsymmetrical ketones,[3] and addition of diethylzinc to aromatic aldehydes.[4] Moreover, chiral benzyl sulfides taking part in a 1,2-amino sulfide subunit can be found in biologically active molecules[5] such as diltiazem[5a] or the ecteinascidine family marine alkaloids, an important group of anticancer agents.[5b]

1,2-Amino alchols, resulting in many cases from the natural amino acids, are the most widely used starting products for synthesizing vicinal amino sulfides. Their stereoselective interconversion has been described according to processes involving the ring opening of aziridine intermediates, which in their term, were obtained from 1,2-amino alcohols under Mitsunobu conditions.[3a,6] A similar strategy is the base of an elegant asymmetric synthesis of β-phenyl cysteine derivatives.[7] 1,2-Amino sulfides[1,4h] and 1,2-amino thiols[4b,e,f] have also been prepared by applying a mesylation of amino alcohol−thiolate displacement sequence, via aziridinium salt intermediate generated by neighboring group participation of the nitrogen. Alternatively, the transformation of the amino alcohols into iminocarbonates (instead of aziridines) and their stereoselective thiolation has been used by Zhu's group[8] to synthesize 1,2-amino sulfides. The usefulness of all these strategies is mainly restricted by the incomplete regioselectivity in the opening reactions on the cyclic intermediates. Additionally, all of them have the problems associated with the asymmetric synthesis of the

† Universidad de Valladolid.
‡ Universidad Autónoma.

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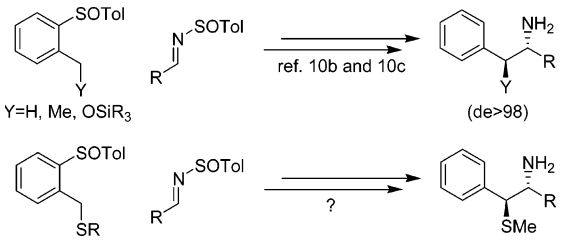
**SCHEME 1**




starting 1,2-amino alcohols. A different approach was used by Enders to prepare *anti*-1,2-amino sulfides, involving the use of the SAMP/RAMP-hydrazone methodology.[9] It consists of the sequential formation of the two chiral centers from optically pure 2-methylthio acetaldehyde SAMP hydrazones, involving an α-alkylation followed by 1,2-addition to C=N bond. Both steps are highly stereoselective, and in some cases, the moderate yields in N,N bond cleavage is a real drawback. Nevertheless, this procedure, which is more general than the others previously cited, cannot be used to introduce aryl residues at the alkylation step, and therefore, the synthesis of the 1,2-diaryl-1,2-amino sulfides must be done by some of the methods starting from 1,2-amino alcohols or some of their most advanced heterocyclic intermediates.

We have recently reported the almost completely stereoselective transference of chiral benzyl groups to different electrophiles from α-alkyl (and trimethylsililoxy) 2-*p*-tolylsulfinylbenzyl carbanions.[10] In these reactions, *N*-sulfinylimines worked as one of the most efficient electrophiles for double-asymmetric induction processes[10b,c] (Scheme 1). Bearing in mind these antecedents, we thought that reactions of *N*-sulfinyl imines with α-thio-2-*p*-tolylsulfinylbenzyl carbanions could provide a new strategy, involving a short number of steps, for the synthesis of 1,2-diaryl- and 1-alkyl-2-aryl-1,2-amino sulfides (Scheme 1). Although the configurational instability of the α-lithio benzyl sulfides is well documented,[11] some examples concerning their highly diastereoselective[12,13] and even enantioselective evolution have been recently reported.[14] These results prompted us to investigate the influence of the *o*-sulfinyl group on the stereoselective evolution of the benzyl carbanions in their reactions with *N*-sulfinylimines. Herein we report the highly stereoselective reaction of the lithium (*S*)-α-methylthio-2-(*p*-toluenesulfinyl)benzyl carbanion Li-(*S*)-**2** with (*S*)-*N*-*p*-tolylsulfinyl aldimines to afford the enantiomerically pure *anti*-1,2-diaryl- and 1-alkyl-2-aryl-1,2-amino sulfide derivatives.

**SCHEME 2. (a) 1. LDA, −78 °C; 2. $Me_2S_2$ (b) LDA, −78 °C**

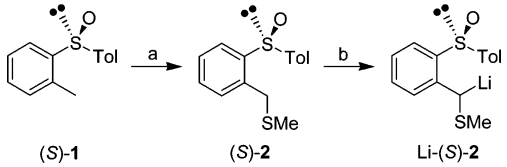
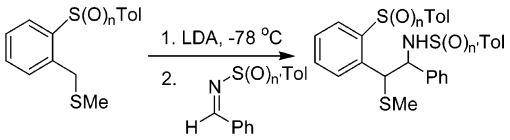



**TABLE 1. Lithiation and Subsequent Electrophilic Substitution of (*S*)-2 and 2′ with Imines 3**




(*S*)-**2** (n=1) **2'** (n=2) | (*S*)-**3a** (n'=1) (*R*)-**3a** (n'=1) **3'a** (n'=2) | **4, 5** (n=n'=1) **6, 7** (n=1, n'=2)

| entry | nucleophile | imine | products (ratio) |
|---|---|---|---|
| 1 | (*S*)-**2** | (*S*)-**3a** | **4a** (>98% de) |
| 2 | (*S*)-**2** | (*R*)-**3a** | **5a/5′a/5″a** (50:20:21) |
| 3 | (*S*)-**2** | **3′a** | complex mixture |
| 4 | **2′** | (*S*)-**3a** | **6a/7a** (80:20) |

## Results and Discussion

(*S*)-α-Methylthio-2-(*p*-tolylsulfinyl)toluene (*S*)-**2** was prepared by deprotonation from enantiopure (*S*)-2-(*p*-tolylsulfinyl)toluene[10b] (*S*)-**1** with LDA and further reaction with dimethyl disulfide, $Me_2S_2$, in 70% yield. The subsequent formation of the α-thiocarbanion required 1.2 equiv of LDA solution (THF) to be stirred for 5 min with (*S*)-**2** at −78 °C before addition of the electrophile. Under these conditions, the formation of a deeply purple solution of Li-(*S*)-**2** was observed (Scheme 2).[15]

To determine the role played by the sulfinyl group at the nucleophile in the stereochemical course of the addition reaction and to identify the matched pair, we first studied the reactions of the α-sulfenyl carbanion Li-(*S*)-**2** with *N*-sulfinylimines (*S*)-**3a** and (*R*)-**3a** and their corresponding sulfone **3′a**. In this context, the reaction of the achiral α-methylthio-2-(*p*-tolylsulfonyl)toluene **2′** was also investigated. In all experiments, the electrophile (2 equiv) was added at −78 °C to the solution of the carbanion. The reaction mixture was kept for 5−10 min at this temperature, and subsequently, workup was performed. The results are shown in Table 1.

Reactions carried out starting from **2′** and (*S*)-**3a** evolved with a 60% de, giving rise to a mixture of two diastereoisomers that have opposite configuration at the two newly created stereogenic centers[16] (Table 1, entry 4). A complex mixture of compounds was obtained in the

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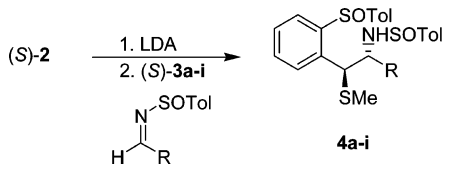
(15) A strict control of the temperature (−78 ± 5 °C) is required for observing the formation of the carbanion.

(16) A enantiomeric pair was obtained when N-desulfinylation of **6a** and **7a**, with TFA/MeOH, was carried out (see the Experimental Section).

**TABLE 2. Lithiation and Subsequent Electrophilic Substitution of (*S*)-2 with (*S*)-*N*-Sulfinylimines 3a−i**




| entry | products | R | isolated yield (%) | de (%) |
|---|---|---|---|---|
| 1 | **4a** | Ph | 85 | >98 |
| 2 | **4b** | *o*-$BrC_6H_4$ | 78 | >98 |
| 3 | **4c** | *p*-$MeOC_6H_4$ | 72 | >98 |
| 4 | **4d** | *p*-$CNC_6H_4$ | 60 | >98 |
| 5 | **4e** | 2-naphthyl | 70 | >98 |
| 6 | **4f** | *n*-Pr | 50 | >98[a] |
| 7 | **4g** | *n*-Bu | 65 | >98[a] |
| 8 | **4h** | *i*-Pr | 70 | >98 |
| 9 | **4i** + **4′i**[b] | *t*-Bu | 70 | 52 |

[a] See text and ref 18. [b] Unknown configuration.

reaction of (*S*)-**2** with the more reactive sulfonamide **3′a** whose complete analysis was not possible in our hands (Table 1, entry 3).[17]

Reaction of (*S*)-**2** with (*R*)-**3a** afforded a mixture of three amino sulfides, whose configurations have not been unequivocally established, with low stereoselectivity (**5a/5′a/5″a** = 50:29:21; Table 1, entry 2). By contrast, only one diastereomeric 1,2-amino sulfide **4a** (>98% de, measured by $^1$H NMR) was obtained in high yield (85%) in the reaction of (*S*)-**2** with (*S*)-**3a** (Table 1, entry 1). These results indicate that the matched pair of the reagents is that formed by the sulfoxide and the imine with identical configuration at sulfur, and a double-induction process is necessary to attain a high stereoselectivity. This situation is consistent with that found in other benzyl carbanions previously studied.[10b,c] Consequently, the (*S*)-*N*-*p*-tolylsulfinylaldimines were chosen as electrophiles for further studies with (*S*)-**2**. The results of these reactions are collected in Table 2.

The reactions with arylaldimines **3b**−**e** afforded 1,2-diaryl-1,2-amino sulfide derivatives **4b**−**e** as single stereoisomers (de >98%), regardless of the electronic character of the substituents at the aryl group (entries 1−5). No other diastereoisomer could be detected by NMR (300 MHz) from the reaction crudes. The isolated yields ranged between 60 and 85%.

Alkylaldimines **3f**−**h** were also studied with analogous results (entries 6−8). It is remarkable that by using only clear solutions of *n*-BuLi to prepare LDA one diastereoisomer was formed in reactions from **3f** and **3g**.[18] Finally, the reaction with the *N*-sulfinylimine derived from pivalaldehyde has also been studied. It affords a 76:24 mixture of two stereoisomers, **4i** and **4′i**, in 70% yield.[19]

The *anti* arrangement of the heteroatomic functions assigned to compounds **4a**−**h** is based on (a) the large value observed for the vicinal coupling constants of their CH−CH fragments ($J \geq 9.5$ Hz, see the Experimental Section), which indicates a quite large conformational preference of the rotamer exhibiting the *anti* arrangement between such a protons. (b) The high value of the vicinal coupling constant $J_{H-N-C-H}$ (7.5−10.4 Hz, see the Experimental Section) reveals the predominance of rotamers exhibiting an *anti* relationship between these protons, which is only possible by assuming that the N−H proton is strongly associated by hydrogen bond with the sulfinyl group. It requires a *gauche* arrangement between the nitrogen function and the aryl group bearing the sulfoxide, which in its term fix the *anti* arrangement of the SMe and NHSOTol groups (Figure 1).

The configurational assignment of compounds **4i** and **4′i** could not be made by using these criteria. **4i** exhibits a very high $J_{H-N-C-H}$ value (9.9 Hz) which indicates that NH must be associated by hydrogen bonds, but $J_{1,2} = 3.4$ Hz, which evidences that H(1) and H(2) adopt a *gauche* arrangement instead of an *anti* one characteristic for all compounds **4**. It could be explained by assuming that **4i** has the same configuration as **4a**−**h** but with the *tert*-butyl and arylsulfinyl groups adopting a *gauche* relationship (Figure 1). The tendency of the *tert*-butyl groups to reach a *gauche* arrangement with respect to phenyl rings is not unexpected because it has been observed for many compounds.[20]

This configurational assignment was unequivocally confirmed in the case of **4a** by X-ray analysis (Figure 1). This study revealed that the absolute configurations of **4a** at its stereogenic centers are 1*R* and 2*S*. This study also proved the existence of an intramolecular hydrogen bonding between the sulfinyl oxygen and the amidic proton for compound **4a**.

The similar behavior observed for all studied aromatic and aliphatic aldimines (all of them evolve in a completely stereoselective manner) also suggests that the absolute configuration for compounds **4b**−**h** is identical to that of **4a**.

An additional check was made in the case of **4g**, whose absolute configuration at C-1 could be demonstrated to be *R* by chemical correlation with amine **8** as previously reported.[10b] Correlation was performed by N-desulfinylation of **4g** with TFA followed by hydrogenolysis with Ra−Ni of the two C−S bonds at the resulting free amine to give optically pure **8**[21] (Scheme 3).

Compounds **4** can be easily transformed into amino sulfides or some of their thioderivatives by selective N- or C-desulfinylation (Scheme 4). Hydrolysis of the N−S bond can be made, without losing optical purity, by reaction with TFA/MeOH, which affords optically pure 1,2-disubstituted-1,2-amino sulfides **9**[22] in high yield. We have illustrated this reaction by studying the transformation of **4a** and **4g** into **9a** and **9g,** respectively (Scheme 4). Otherwise, hydrogenolysis of the Ar−SOTol bond can be made by reaction of the sulfoxides with organolithium

(17) The signals of several amino sulfides, probably more than two, could be recognized in the $^1$H NMR spectrum of the crude reaction obtained from **3′a** but they could not be isolated.

(18) Otherwise a 86:14 mixture of two diastereoisomers (**4f** + **4′f** from **3f** and **4g** + **4′g** from **3g**) were formed, presumably due to the partial racemization at the benzyl carbon, as it has been previously reported for other benzylthioethers in the presence of lithium salts (lithium alcoholates or thiolates). See ref 12a and the Experimental Section.

(19) The configurational assignment of the minor isomer has not been unequivocally established.

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(21) Specific rotation of compound **8**: $[\alpha]^{20}_D = -4.7$ (*c* 0.5, MeOH) [lit.[10b] $[\alpha]^{20}_D = -4.5$ (*c* 0.7, MeOH)].

(22) De values higher than 98% were determined by using the Mosher amides protocol.

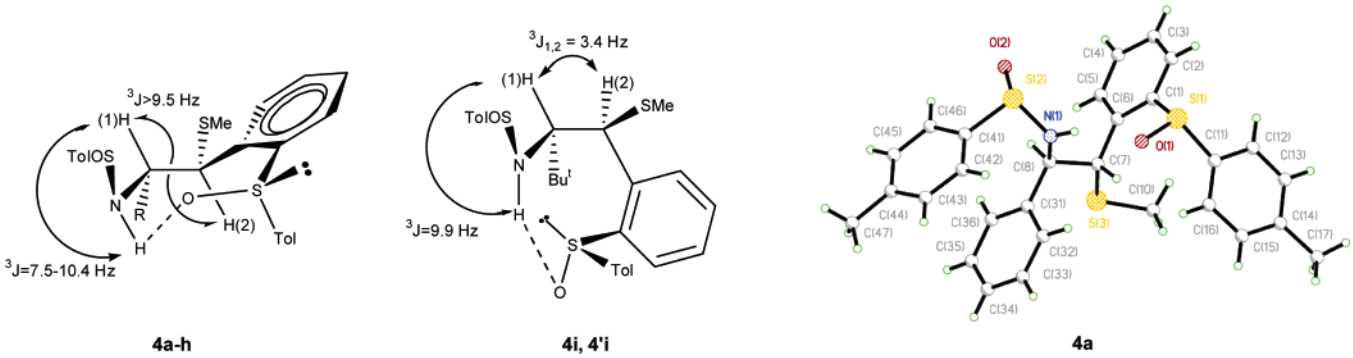
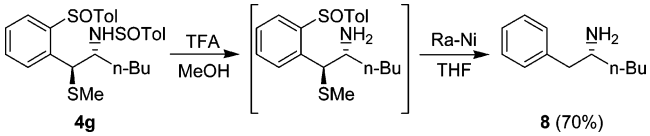
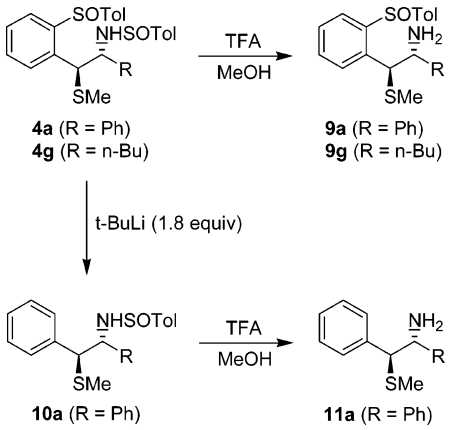



**FIGURE 1.** Values of the vicinal coupling constant for compounds **4** and X-ray structure for **4a**.

**SCHEME 3**




**SCHEME 4**




compounds following reported procedures.[23] Thus, desulfinylation of **4a** with *t*-BuLi (1.8 equiv) affords the N-protected amino sulfide **10a** in nearly quantitative yield. It can be converted into the optically pure amino sulfide **11a**[24] by reaction with TFA/MeOH. Reaction of **9a** with *t*-BuLi yielded a complex reaction mixture.

These results suggest that compounds **4** can be used for preparing the amino sulfides **11** and their N-protected derivatives **10**, able to act as a bidentate ligands. Also, derivatives **9**, containing an additional sulfinyl group, are interesting since they could be used as tridentate chelating N,S,O-ligands exhibiting a different ability to coordinate to metal transition ions.[25] Moreover, manipulation of the sulfide functionality allows interesting chemical transformations of these compounds.[26]

The stereochemical outcome of this reaction can be rationalized according to four-membered cyclic transition states, **TS-1** and **TS-2**, similar to those proposed for other benzylcarbanions, both evolving with retention of the configuration at benzylic carbon[10a,b] (Figure 2). They

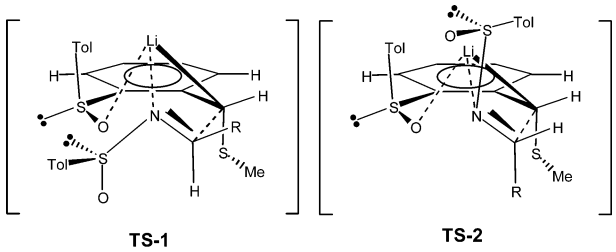



**FIGURE 2.** Plausible transition states of the reaction of Li−(*S*)-**2** with (*S*)-*N*-sulfinylimines.

result in the two possible approaches of the (*S*)-imine to the presumably most stable conformation of the nucleophilic carbanion derived from (*S*)-**2**, which is that depicted in Figure 2. It displays the tolyl and SMe groups in a pseudoaxial arrangement avoiding the benzylic strain with their ortho protons. Moreover, the pseudoaxial arrangement of the S−Me group must be favored because it allows the stabilization of the α-thio-substituted carbanions by n−$\sigma_{S-C^*}$ overlapping which requires an antiperiplanar arrangement of the S−$CH_3$ and C−Li bonds[27] (such arrangement would be destabilized for conformations with the SMe group in pseudoequatorial orientation due to its steric interactions with the ortho proton).[28]

On the basis on the steric interactions, **TS-1** (affording compounds *anti*) must be clearly favored with respect to

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**TS-2** (yielding the *syn* isomers) for the matched pair of reagents. Changes in the configuration at the starting *N*-sulfinylimine would decrease the stability difference between **TS-2** (it would become more stable) and **TS-1**[29] (it would be less stable), thus decreasing the stereoselectivity as observed for the mismatched pair. The prevalent role of the sulfinyl group at the carbanion on the stereoselectivity of these reactions is supported by the moderated stereoselectivity observed when the sulfonyl carbanion derived from **2′** reacts with (*S*)-**2**[30] (Table 1, entry 4).

## Conclusion

In summary, we have described a highly stereoselective reaction of the lithium (*S*)-2-(*p*-toluenesulfinyl)-α-(methylthio)benzyl carbanion, Li-(*S*)-**2**, with aromatic and aliphatic (*S*)-*N*-sulfinylaldimines **3**. This reaction provides an efficient method for the preparation of optically pure *anti*-1,2-diaryl (with identical or different aromatic residues) and 1-alkyl-2-aryl-1,2-amino sulfides derivatives, **4**, which can be transformed into interesting bicoordinative S,N (**10** and **11**) or tricoordinative S,N,O (**9**) ligands.

## Experimental Section

**Synthesis of (*S*)-α-Methylthio-2-(*p*-tolylsulfinyl)toluene (2).** A solution of *n*-BuLi 1.6 M in hexane (1.1 mL, 1.74 mmol, 1.2 equiv) was added over $^{i}Pr_2NH$ (0.37 mL, 2.61 mmol, 1.8 equiv) in THF (4 mL) at 0 °C. After 45 min of stirring, the mixture was cooled at −78 °C, and then a solution of (*S*)-2-*p*-tolylsulfinyltoluene[10b] (400 mg, 1.45 mmol, 1.0 equiv) in THF (3 mL) was added. After 15 min of stirring, $(CH_3)_2S_2$ (3.9 mmol, 2 equiv) was added at −78 °C. When the reaction was completed (30 min), the mixture was hydrolyzed at that temperature with saturated aqueous $NH_4Cl$ solution (2 mL) and extracted with $CH_2Cl_2$ (3 × 10 mL). The combined organic layers were dried over $MgSO_4$, and the solvent was removed under reduced pressure. The residue was purified by flash-column chromatography (hexane/$Et_2O$ 1:1) to give pure compound **2** (70%): $[\alpha]^{20}_D = -147.6$ (*c* 1.1, $CHCl_3$); $^1H$ NMR (300 MHz, $CDCl_3$) δ 7.87−7.82 (m, 1H), 7.54 and 7.23 (AA′BB′ system, 4H), 7.44−7.31 (m, 3H), 3.84 (AB system, 2H, $J_{gem}$ = 13.8 Hz), 2.34 (s, 3H), 2.00 (s, 3H); $^{13}C$ NMR (75 MHz, $CDCl_3$) δ 143.9, 141.4, 141.3, 136.5, 130.9, 130.0, 129.8, 128.4, 125.8, 125.5, 34.2 , 21.2, 15.1; HRMS calcd for $C_{15}H_{16}OS_2$ 276.0643, found 276.0639.

**General Procedure for the Reactions Summarized in Tables 1 and 2.** A solution of *n*-BuLi 1.6 M in hexane (0.60 mmol, 1.2 equiv) was added over $^{i}Pr_2NH$ (0.89 mmol, 1.8 equiv) in THF (3 mL) at 0 °C. After 45 min of stirring, the mixture was cooled at −78 °C and then a solution of the nucleophile [(*S*)-**2** or **2′**; 0.50 mmol, 1.0 equiv] in THF (2 mL) was added. After 5 min of stirring, the electrophile [sulfinylimine[31] (**3a**−**i**), 1.0 mmol, 2.0 equiv] dissolved in THF (4 mL) was added at −78 °C. When the reaction was completed (5−10 min), the mixture was hydrolyzed at that temperature with saturated aqueous $NH_4Cl$ solution (2 mL) and extracted with $CH_2Cl_2$ (3 × 10 mL). The combined organic layers were dried over $MgSO_4$, and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography.

**[1*R*,2*S*,(S)*S*]-*N*-{1-Phenyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4a):** eluent for chromatography hexane/$Et_2O$ 1:4; yield 85%; white solid; mp 107−108 °C (hexane/$Et_2O$); $[\alpha]^{20}_D = +78.3$ (*c* 1.2, $CHCl_3$); $^1H$ NMR δ 7.88 (dd, 2H, *J* = 7.6 and 1.4 Hz), 7.72 and 7.52 (2td, 2H, *J* = 7.6 and 1.4 Hz), 7.42 (part of AA′BB′ system), 7.20−7.11 (m, 5H), 6.94 (bs, 4H), 6.10 (d, 1H, *J* = 8.1 Hz), 4.66 (d, 1H, *J* = 10.4 Hz), 4.35 (dd, 1H, *J* = 10.4 and *J* = 8.1 Hz), 2.30 and 2.29 (two s, 6H), 0.87 (s, 3H); $^{13}C$ NMR δ 141.9, 141.7, 141.6, 141.2, 140.7, 140.4, 133.1, 130.9, 129.3, 128,7, 128.5, 128.0, 127.8, 127.3, 125.8, 125.0, 61.9, 50.3, 21.2, 15.3. HRMS calcd for $C_{29}H_{29}NO_2S_3$ 519.1361, found 519.1368.

**[(S)*R*]-N-{1-Phenyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (5a):** eluent for chromatography hexane/$Et_2O$ 1:4; yield 55%; colorless oil; $[\alpha]^{20}_D = -112.6$ (*c* 0.5, $CHCl_3$); $^1H$ NMR δ 7.55 (d, 2H, *J* = 7.7 Hz), 7.45−7.20 (m, 7H), 7.11, 6.99, 6.92 and 6.86 (two AA′BB′ system, 8H), 5.65 (d, 1H, *J* = 3.2 Hz), 4.95−4.88 (m, 2H), 2.33 and 2.25 (two s, 6H), 1.82 (s, 3H); $^{13}C$ NMR δ 143.8, 141.0, 140.9, 140.6, 140.1, 140.0, 139.3, 131.5, 129.7, 129.5, 128.9, 128.5, 127.9, 127.4, 126.9, 125.6, 125.5, 57.7, 51.8, 21.3 and 21.2, 13.5; MS (EI) *m/z* (relative intensity) 519 (3, $M^+$), 380 (5), 211 (100), 139 (56), 106 (80).

**[1*R*,2*S*,(S)*S*]-*N*-{1-(*o*-Bromophenyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4b):** eluent for chromatography hexane/$Et_2O$ 1:5; yield 78%; white solid; mp 153−154 °C (hexane/$Et_2O$); $[\alpha]^{20}_D = +75.0$ (*c* 0.5, $CHCl_3$); $^1H$ NMR: δ 7.93 and 7.82 (two dd, 2H, *J* = 7.6 and 0.9 Hz), 7.72, 7.63, 7.53 and 7.34 (four td, 4H, *J* = 7.5 and 0.9 Hz), 7.42, 7.23, 6.99 and 6.92 (two AA′BB′ system, 8H), 7.05−7.00 (m, 2H), 6.56 (d, 1H, *J* = 7.5 Hz), 5.04 (dd, 1H, *J* = 10.3 and 7.5 Hz), 4.69 (d, 1H, *J* = 10.3 Hz), 2.31 and 2.27 (two s, 6H), 0.84 (s, 3H); $^{13}C$ NMR δ 141.7, 141.3, 141.2, 140.8, 140.5, 140.3, 133.3, 131.9, 131.3, 130.0, 128.8, 127.9, 126.6, 125.9, 124.8, 58.4, 51.2, 21.2, 14.1. calcd for $C_{29}H_{28}BrNO_2S_3$ 599.0445, found 599.0427.

**[1*R*,2*S*,(S)*S*]-*N*-{1-(*p*-Methoxyphenyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4c):** eluent for chromatography hexane/$Et_2O$ 1:5; yield 72%; white solid; mp 117−118 °C (hexane/$Et_2O$); $[\alpha]^{20}_D = +48.1$ (*c* 1.0, $CHCl_3$); $^1H$ NMR δ 7.87 (dc, 1H, *J* = 7.6 and 1.1 Hz), 7.71 and 7.54 (two td, 2H, *J* = 7.6 and 1.1 Hz), 7.41, 7.15, 7.07, 6.98 and 6.92, 6.75 (three AA′BB′ system, 12H), 5.84 (d, 1H, *J* = 8.2 Hz), 4.66 (d, 1H, *J* = 10.4 Hz), 4.33 (dd, 1H, *J* = 10.4 and 8.2 Hz), 3.78 (s, 3H), 2.31 and 2.30 (two s, 6H), 0.95 (s, 3H); $^{13}C$ NMR δ 158.8, 141.9, 141.8, 141.7, 141.3, 140.7, 140.3 and 134.0, 133.0, 130.7, 130.0, 128.7, 128.4, 127.8, 125.7, 125.1, 113.5, 61.8, 50.5, 55.1, 21.2, 14.3; calcd for $C_{30}H_{31}NO_3S_3$ 549.1466, found 549.1453.

**[1*R*,2*S*,(S)*S*]-*N*-{1-(*p*-Cyanophenyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4d):** eluent for chromatography hexane/$Et_2O$ 1:5; yield 60%; white solid; mp 135−136 °C (hexane/$Et_2O$); $[\alpha]^{20}_D = +59.0$ (*c* 0.6, $CHCl_3$); $^1H$ NMR δ 7.92 and 7.83 (two dd, 2H, *J* = 7.6 and 0.9 Hz), 7.77 and 7.56 (two td, 2H, *J* = 7.6 and 0.9 Hz), 7.45, 7.39, 7.24, 7.22, 6.97 and 6.93 (three AA′BB′ system, 12H), 6.85 (d, 1H, *J* = 7.6 Hz), 4.61 (d, 1H, *J* = 10.7 Hz), 4.31 (dd, 1H, *J* = 10.7 and 7.6 Hz), 2.33 and 2.29 (two s, 6H), 0.66 (s, 3H); $^{13}C$ NMR δ 147.9, 141.4, 141.2, 141.1, 140.9, 140.7, 140.4, 133.6, 131.6, 131.4, 130.1, 129.6, 128.7, 128.3, 128.0, 125.8, 124.5, 59.9, 49.6, 21.2, 14.0; calcd for $C_{30}H_{28}N_2O_2S_3$ 544.1313, found 544.1306.

**[1*R*,2S,(S)*S*]-*N*-{1-(2-Naphthyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4e):** eluent for chromatography hexane/$Et_2O$ 1:5; yield 70%; white solid; mp 101−102 °C (hexane/$Et_2O$); $[\alpha]^{20}_D = +122.0$ (*c* 0.5, $CHCl_3$); $^1H$ NMR δ 7.94 and 7.88 (2dd, 2H, *J* = 7.7 and 1.2 Hz), 7.79−7.40 (m, 9H), 7.45, 7.18, 6.97, and 6.77 (two

(29) It can be easily deduced from Figure 2 by changing the relative position of the O and Tol groups at the *N*-sulfinyl moiety, because the interaction $(Tol/H)_{1,3-parallel}$ is higher than $(O/H)_{1,3-parallel}$.

(30) Benzylation of optically pure *N*-sulfinylimines with organometallic does not usually evolve with complete stereoselectivity (see ref 10b). The higher acidity of the benzyl protons at **6a** and **7a** could have some role in the obtained **6a/7a** ratio (Table 1, entry 4).

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AA′BB′ system, 8H), 6.37 (d, 1H, $J$ = 7.7 Hz), 4.78 (d, 1H, $J$ = 10.6 Hz), 4.49 (dd, 1H, $J$ = 10.6 and 7.7 Hz), 2.29 and 2.10 (two s, 6H), 0.77 (s, 3H); $^{13}$C NMR $\delta$ 141.7, 141.5, 141.2, 140.8, 140.6, 140.4, 139.0, 132.7, 132.6, 133.3, 131.1, 130.0, 129.6, 128.8, 128.5, 128.1, 127.8, 127.5, 126.9, 125.8, 125.7 124.8, 124.6, 61.1, 49.7, 21.2, 20.9, 14.3; calcd for $C_{33}H_{31}NO_2S_3$ 569.1517, found 569.1515.

**[1*R*,2*S*,(S)*S*]-*N*-{1-Propyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4f):** eluent for chromatography hexane/$Et_2O$ 1:1; yield 50%; white solid; mp 80−81 °C (hexane/$Et_2O$); $[\alpha]^{20}_D$ = +50 (*c* 0.5, $CHCl_3$); $^1$H NMR $\delta$ 7.95 and 7.78 (two dd, 2H, $J$ = 7.6 and 1.3 Hz), 7.65−7.51 (m, 2H), 7.30, 7.07, 6.93 and 6.72 (two AA′BB′ system, 8H), 4.35 (d, 1H, $J$ = 9.6 Hz), 3.68−3.57 (m, 2H), 2.37 and 2.25 (two s, 6H), 1.62 (s, 3H), 1.60−1.21 (m, 4H), 0.93 (t, 3H, $J$ = 7.1 Hz); $^{13}$C NMR $\delta$ 143.3, 142.3, 141.8, 141.1, 140.8, 140.6, 132.2, 129.8, 129.5, 129.1, 127.8, 125.9,125.4, 125.2, 61.2, 49.5, 37.0, 17.7, 21.3, 14.2, 14.0; calcd for $C_{26}H_{31}NO_2S_3$ 485.1517, found 485.1496.

**[(S)*S*]-*N*-{1-Propyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4′f).** This product has only been detected when a cloudy solution of *n*-BuLi was used in reaction with sulfinylimine **3f**: eluent for chromatography hexane/$Et_2O$ 1:1; yield 10%; white syrup; $[\alpha]^{20}_D$ = −30 (*c* 0.3, $CHCl_3$); $^1$H NMR $\delta$ 8.17 and 7.74 (two dd, 2H, $J$ = 6.3 and 1.4 Hz), 7.83, 7.61, 7.31 and 7.25 (two AA′BB′ system, 8H), 7.62−7.44 (m, 2H), 4.72 (d, 1H, $J$ = 4.2 Hz), 4.51 (d, 1H, $J$ = 10.4 Hz), 3.92−3.79 (m, 1H), 2.43 and 2.34 (two s, 6H), 1.61 (s, 3H), 1.61−1.15 (m, 4H), 0.84 (t, 3H, $J$ = 7.0 Hz).

**[1*R*,2*S*,(S)*S*]-*N*-{1-Butyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4g):** eluent for chromatography hexane/$Et_2O$ 1:1.5. yield 65%; white solid; mp 96−97 °C (hexane/$Et_2O$); $[\alpha]^{20}_D$ = +49.5 (*c* 0.5, $CHCl_3$); $^1$H NMR $\delta$ 7.92 and 7.77 (two dd, 2H, $J$ = 7.6 and 1.3 Hz), 7.64−7.51 (m, 2H), 7.29, 7.06, 6.91 and 6.72 (two AA′BB′ system, 8H), 4.34 (d, 1H, $J$ = 9.8 Hz), 3.63 (d, 1H, $J$ = 9.3 Hz), 3.65−3.50 (m, 1H), 2.35 and 2.23 (two s, 6H), 1.60 (s, 3H), 1.59−1.12 (m, 6H), 0.92 (t, 3H, $J$ = 7.3 Hz); $^{13}$C NMR $\delta$ 143.2, 142.2, 141.8, 141,1, 140.8, 140.5, 132.1, 129.7, 129.0, 127.8, 127.0, 126.0, 125.4, 125.2, 61.1, 49.3, 34.4, 26.3, 22.5, 21.3, 14.1, 13.9; calcd for $C_{27}H_{33}NO_2S_3$ 499.1673, found 499.1675.

**[(S)*S*]-*N*-{1-Butyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4′g).** This product has only been detected when a cloudy solution of *n*-BuLi was used in reaction with sulfinylimine **3g**: eluent for chromatography hexane/$Et_2O$ 1:1.5; yield 10%; white syrup; $[\alpha]^{20}_D$ = −36 (*c* 0.3, $CHCl_3$); $^1$H NMR $\delta$ 8.16 and 7.73 (two dd, 2H, $J$ = 7.7 and 1.4 Hz), 7.56−7.46 (m, 2H), 7.80, 7.61, 7.32 and 7.25 (two AA′BB′ system, 8H), 4.72 (d, 1H, $J$ = 4.3 Hz), 4.52 (d, 1H, $J$ = 10.4 Hz), 3.92−3.79 (m, 1H), 2.43 and 2.34 (two s, 6H), 1.48 (s, 3H), 1.52−1.10 (m, 6H), 0.83 (t, 3H, $J$ = 7.1 Hz).

**[1*R*,2*S*,(S)*S*]-*N*-{1-Isopropyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4h):** eluent for chromatography hexane/$Et_2O$ 1:5; yield 70%; white solid; mp 77−78 °C (hexane/$Et_2O$); $[\alpha]^{20}_D$ = +32.1 (*c* 1.0, $CHCl_3$); $^1$H NMR $\delta$ 7.88 and 7.81 (two dd, 2H, $J$ = 7.6 and 1.2 Hz), 7.66 and 7.57 (two dt, 2H, $J$ = 7.6 and 1.2 Hz), 7.23, 7.01, 6.94 and 6.51 (two AA′BB′ system, 8H), 4.40 (d, 1H, $J$ = 10.9 Hz), 3.96 (d, 1H, $J$ = 10.4 Hz), 3.61−3.50 (m, 1H), 2.45−2.32 (m, 1H), 2.36 and 2.26 (two s, 6H), 1.44 (s, 3H), 1.15 and 0.86 (2d, 6H, $J$ = 6.8 Hz; $^{13}$C NMR $\delta$ 143.0, 142.9, 142.0, 141.7, 140.7, 140.3, 132.4, 130.0, 129.0, 127.6, 126.8, 125.6, 124.8, 68.0, 47.1, 29.1, 21.0, 15.1, 13.9; calcd for $C_{26}H_{31}NO_2S_3$ 485.1517, found 485.1502.

**[1*R*,2*S*,(S)*S*]-*N*-{1-*tert*-Butyl-2-[(*S*)-2-(*p*-toluensulfinyl)-phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4i):** eluent for chromatography hexane/$Et_2O$ 1:3; yield 60%; white solid; mp 47−48 °C (hexane/$Et_2O$); $[\alpha]^{20}_D$ = −81.0 (*c* 0.5, $CHCl_3$); $^1$H NMR $\delta$ 8.12−8.01 (two m, 2H), 7.68, 7.65, 7.32 and 7.25 (two AA′BB′ system, 8H), 7.47 (dd, 2H, $J$ = 8.2 and 0.8 Hz), 4.73 (d, 1H, $J$ = 3.4 Hz), 4.52 (d, 1H, $J$ = 9.9 Hz), 3.82 (dd, 1H, $J$ = 9.9 and 3.4 Hz), 2.42 and 2.35 (two s, 6H), 1.64 (s, 3H), 0.94 (s, 9H); $^{13}$C NMR $\delta$ 144.0, 142.1, 141.5, 141.3, 136.8, 131.7, 131.2, 130.0, 129.6, 128.8, 126.2, 124.9, 124.4, 69.3, 37.7, 28.2, 21.3, 15.7; calcd for $C_{27}H_{33}NO_2S_3$ 499.1674, found 499.1688.

**[(S)*S*]-*N*-{1-*tert*-Butyl-2-[(*S*)-2-(*p*-toluensulfinyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (4′i):** eluent for chromatography hexane/$Et_2O$ 1:3; yield 18%; white syrup; $[\alpha]^{20}_D$ = +59 (*c* 1, $CHCl_3$); $^1$H NMR $\delta$ 8.01 and 7.74 (two d, 2H, $J$ = 7.8 Hz), 7.63−7.58 and 7.46−7.42 (two m, 2H), 7.61, 7.45, 7.29 and 7.27 (two AA′BB′ system, 8H), 4.98 (d, 1H, $J$ = 7.8 Hz), 4.83 (d, 1H, $J$ = 3.1 Hz), 3.53 (dd, 1H, $J$ = 7.8 and 3.1 Hz), 2.42 and 2.38 (two s, 6H), 1.72 (s, 3H), 0.91 (s, 9H).

**[(S)*S*]-*N*-{1-Phenyl-2-[2-(*p*-toluensulfonyl)phenyl]-2-(methylthio)ethyl}-*p*-toluenesulfinamide (6a):** eluent for chromatography hexane/$Et_2O$ 1:4; yield 85%; white syrup; $[\alpha]^{20}_D$ = +113.5 (*c* 0.5, $CHCl_3$); $^1$H NMR $\delta$ 8.02 and 7.83 (two dd, 2H, $J$ = 7.1 and 0.9 Hz), 7.72−7.55 (m, 2H), 7.43 (t, 1H, $J$ = 7.1 Hz), 7.29−7.11 (m, 4H), 7.63, 7.09, 6.87 and 6.78 (two AA′BB′ system, 8H), 5.23 (d, 1H, $J$ = 8.7 Hz), 4.85 (d, 1H, $J$ = 10.5 Hz), 4.41 (dd, 1H, $J$ = 8.7 and 10.5 Hz), 2.25 and 2.20 (two s, 6H), 0.92 (s, 3H).

**Representative Procedure for C−S Desulfinylation.** To a stirred solution of **4a** (0.12 mmol) in THF (2 mL) was added *t*-BuLi (0.15 mL, 0.22 mmol, 1.5 M in hexane, 1.8 equiv). When the reaction was completed (5 min), the mixture was hydrolyzed with saturated aqueous $NH_4Cl$ solution (1 mL) and extracted with $CH_2Cl_2$ (3 × 3 mL). The combined organic layers were dried over $MgSO_4$, and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography (hexane/$Et_2O$ 1:1) to give pure **10a** in quantitative yield: colorless syrup; $[\alpha]^{20}_D$ = +155.8 (*c* 0.7, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.33−7.21 (m, 7H), 7.20−7.15 (m, 3H), 7.00−6.98 (m, 2H), 4.76 (dd, 1H, $J$ = 6.1 and 6.5 Hz), 4.75 (bs, 1H), 4.21 (d, 1H, $J$ = 6.5 Hz) 2.31 (s, 3H), 1.84 (s, 3H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 141.2, 141.0, 139.4, 138.4, 129.1, 128.4, 127.9, 127.6, 125.6, 61.2, 59.4, 21.2 , 14.9.

**Representative Procedure for N−S Desulfinylation.** To a stirred solution of **4a**, **4g**, or **10a** (0.05 mmol) in methanol (1 mL) was added TFA (12.5 $\mu$L, 0.15 mmol, 3 equiv). After the mixture was stirred for 3 h at 0 °C, the solvent was evaporated, and the residue was purified by SCX column chromatography to afford the corresponding amine.

**(1*S*)-1-Phenyl-2-[(*S*)-2-(p-toluensulfinyl)phenyl]-2-(methylthio)ethylamine (9a).** This product was obtained from **4a**: yield 90%; yellow oil; $[\alpha]^{20}_D$ = −155 (*c* 0.5, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.84 and 7.72 (2dd, 2H, $J$ = 7.6 and 0.9 Hz), 7.57 and 7.28 (AA′BB′ system, 4H), 7.56 (d, 1H, $J$ = 8.0 Hz), 7.50−7.31 (m, 6H), 4.69 and 4.13 (2d, 2H, $J$ = 8.5 Hz), 2.37 (s, 3H), 1.98 (bs, 2H), 1.41 (s, 3H).

**(1*R*)-1-[(*S*)-2-(*p*-Toluensulfinyl)-1-(methylthio)benzyl]-pentylamine (9g).** This product was obtained from **4g**: Yield 90%; yellow oil; $[\alpha]^{20}_D$ = −23.5 (*c* 0.5, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.88 and 7.66 (2dd, 2H, $J$ = 7.7 and 0.8 Hz), 7.52 and 7.24 (AA′BB′ system, 4H), 7.50−7.41 (m, 2H), 4.22 (d, 1H, $J$ = 8.4 Hz), 2.91 (dt, 1H, $J$ = 8.4 and 2.0 Hz) 2.35 (s, 3H), 1.70 (s, 3H), 1.45−1.16 (m, 6H), 1.40 (bs, 2H), 0.87 (t, 3H, $J$ = 7.0 Hz).

**(1*R*,2*S*)-2-(Methylthio)-1,2-diphenylethylamine (11a).** This product was obtained from **10a**: yield quantitative; colorless oil; $[\alpha]^{20}_D$ = +49.5 (*c* 0.5, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.42−7.29 (m, 10H), 4.29 (bs, 1H), 3.93 (d, 1H, $J$ = 8.3 Hz) 2.03 (bs, 2H), 1.71 (s, 3H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 139.4, 137.0, 128.8, 128.6, 128.3, 127.9, 127.6, 127.3, 58.1, 49.9, 15.0.

**1-Phenyl-2-[2-(*p*-toluensulfonyl)phenyl]-2-(methylthio)ethylamine (12a).** This product was obtained from **6a** and **7a**: yield 90%; yellow oil; $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 8.19 and 7.75 (2dd, 2H, $J$ = 8.0 and 1.1 Hz), 7.65 and 7.47 (2dt, 2H, $J$ = 8.0 and 1.1 Hz), 7.82 and 7.32 (AA′BB′ system, 4H), 7.40−7.29 (m, 5H), 4.92 and 4.01 (two d, 2H, $J$ = 9.1 Hz), 2.40 (s, 3H), 1.98 (bs, 2H), 1.07 (s, 3H).

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**Supporting Information Available:** $^{1}H$ and $^{13}C$ NMR spectra of compounds **2**, **4a**−**i**, **4′f**, **4′g**, **4′i**, **5a**, **6a**, **9a**,**g**, **10a**, **11a**, and **12a** and complete data of X-ray crystal structure of **4a**. X-ray crystal structure of **4a** (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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